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Industrial Crops and Products 21 (2005) 353–359

INDUSTRIAL CROPS AND PRODUCTS
AN INTERNATIONAL JOURNAL

www.elsevier.com/locate/indcrop

Batch drying of cuphea seeds

Steven C. Cermak [a,*], Terry A. Isbell [a], Judd E. Isbell [b], Gregory G. Akerman [c], Benjamin A. Lowery [a], Amy B. Deppe [a]

[a] *New Crops and Processing Technology Research, National Center for Agricultural Utilization Research, USDA1, Agricultural Research Service, 1815 N. University St., Peoria, IL 61604, USA*
[b] *Isbell Farm Consulting, 12802 Center St., Hanna City, IL 61536, USA*
[c] *Cube Inc., 1815 N. University St., Peoria, IL 61604, USA*

Received 2 June 2003; accepted 13 May 2004

Abstract

Fresh mechanically harvested cuphea seed from the Midwest contains more than 50% moisture. Such high moisture leads to challenging drying problems. Cuphea seeds must be dried immediately to reduce moisture before destructive seed mold and material-clumping develop. A method had to be developed to batch dry large quantities of cuphea seeds. The freshly harvested, wet, uncleaned seeds were dried using a Grain Technology 245XL Dryer. Drier conditions were optimized over a 2 year period to yield a procedure for a batch drying process. In this process, the grain dryer was modified to help meet the demands of a small seed that has greater than 50% moisture at harvest. The seed moisture data was collected on a low-cost, commercially available G-7 Grain Moisture Meter, which can be used for different crops. The meter showed a strong correlation between the soybean setting and actual cuphea moisture content (%) measured in the lab when seed moisture was less than 20%. The cuphea seeds were dried to about 12% for storage.
Published by Elsevier B.V.

Keywords: Cuphea; Drying; Grain technology; Moisture; Seed

1. Introduction

Cuphea (Lythraceae) is an annual plant that produces a small oil seed that is rich in saturated, medium-chain triacyglycerols (Wolf et al., 1983). Oil characterization for a number of cuphea species was first made in the early 1960’s by Miller et al. (1964). As with most new crops, many obstacles must be overcome before a wild plant can become a major industrial crop. One of cuphea’s major problems is seed shattering, a condition that causes seeds to be released from the pod as they mature. A breeding selection was made where seed retention was improved (Knapp, 1992). This new variety retains most of the seed from being released onto the ground, and thus can be mechanically harvested.

A second problem with cuphea is its indeterminate growth behavior. The plant continues to flower and develop seed. This indeterminate growth characteristic results in a range of seed maturities within individual plants and correspondingly a vast range in seed moisture throughout the field. Consequently, when the field

* Corresponding author. Tel.: +1 309 6816233; fax: +1 309 6816524.
E-mail address: cermaksc@ncaur.usda.gov (S.C. Cermak).

0926-6690/$ – see front matter. Published by Elsevier B.V.
doi:10.1016/j.indcrop.2004.05.003

harvest has large numbers of high moisture immature seeds, the bulk seed moisture is very high (>50%). These high seed moisture contents cause numerous handling and storage problems.

Target seed moisture contents vary depending on the intended use of the harvested seed. Our interest in cuphea is for the extraction of high caprin oil. Thus, seeds used for pressing, expelling oil are usually dried to 3–6% moisture before processing. Unfortunately, the limited supply of cuphea seed to date also necessitates that harvested seed be used for replanting to increase seed production. Seeds used for planting are usually dried to 11–13% moisture, but lower moisture levels do not decrease cuphea seed germination (Crane et al., 2003).

Commercial production research on cuphea has been conducted for the past 3 years at the USDA site in Morris, Minnesota and Peoria, Illinois, USA (Isbell, 2002). Seed moisture in these studies has been greater than 50%. This high seed moisture level presents problems in transporting seed (difficulties in augers including auger bridging), clumping, rapid (overnight) mold development, and extreme seed heating "pile effect" due to the exothermic seed respiration process. In the first year, the crop was mechanically harvested and the seeds spread on the ground to dry. Unfortunately, this method caused the seeds to clump together during transportation and had to be broken apart as well as be mixed with rakes. This procedure was labor-intensive and not practical. Consequently, our objectives were to develop a method for drying cuphea on a batch scale and a procedure for the rapid moisture determination that can be used in the field based on a commercially available moisture meter.

2. Materials and methods

2.1. Materials

Cuphea seeds are a flat round seed with a diameter of about 3 mm (3 g per 1000 seeds). Two lots of seed were used for this study. Cuphea seeds planted in mid-May were mechanically harvested with a John Deere 4400 concave cylinder combine in late October from test plots at the North Central Soil Conservation Research Laboratory (NCSCRL) in Morris, Minnesota and in September at the University of Illinois, Champaign-Urbana, Illinois, with an International 815 concave cylinder corn and soybean special combine.

2.2. Equipment and procedures

2.2.1. Grain dryer operation

The Grain Technology 245XL Grain Dryer from GT Mfg., Inc. (Clay City, Kansas) was coupled to a power take off, PTO (Fig. 1, A) from a 1940 Ford 9N Tractor (Dearborn, Michigan) that provided 14914 J/s at 53.5 rad/s. The seed dryer cost in 2002 was approximately US $12000. The approximate size of the dryer is as follows: overall height 4.14 m, width 2.51 m, length 6.55 m with hopper extended and a total volume 8.56 m^3. Operation of the dryer was as follows (Fig. 1): seeds flowed from the top of the vertical auger, C, and fell onto the top of the plenum cone, F. As the seeds fell past the plenum, heat from the burner, B, drove off the moisture. The seeds continued to fall until they reached the fill level in the dryer. From this point on, the seed has continuous warm air passing through it while making its way down. As the seeds reached the cone bottom (Fig. 1, J), an agitator mixed the seeds keeping them from sticking together and onto the outer cone. Arm-1 (Fig. 2, un-modified) mixes the seeds at the bottom of the lower cone, and the Arm-2 (Fig. 2, un-modified) helped mix seeds down to the lower bin and side wall. Once the seeds are in the lower bin, G, the seeds make their way to the vertical auger, E, and are lifted to the top to start the process again. The outside skin and the plenum were made of a galvanized steel mesh (0.159 cm) to allow the heat and moisture to escape.

2.2.1.1. Plenum temperature control. The plenum temperature control is located inside the control panel, M, (Fig. 1, F). The plenum temperature effects how fast the moisture will be removed from the seed, lowering the plenum temperature increases drying time. Plenum temperature was measured with a sensor located inside the plenum (Fig. 1) K. For these trials the plenum temperature was set to 65.6 °C, the plenum temperatures readings were recorded in Table 1.

2.2.1.2. Grain temperature and control. The grain temperature control is located inside the control panel, M, and serves to prevent over-heating of grain. This is measured with a sensor located on the inside lower

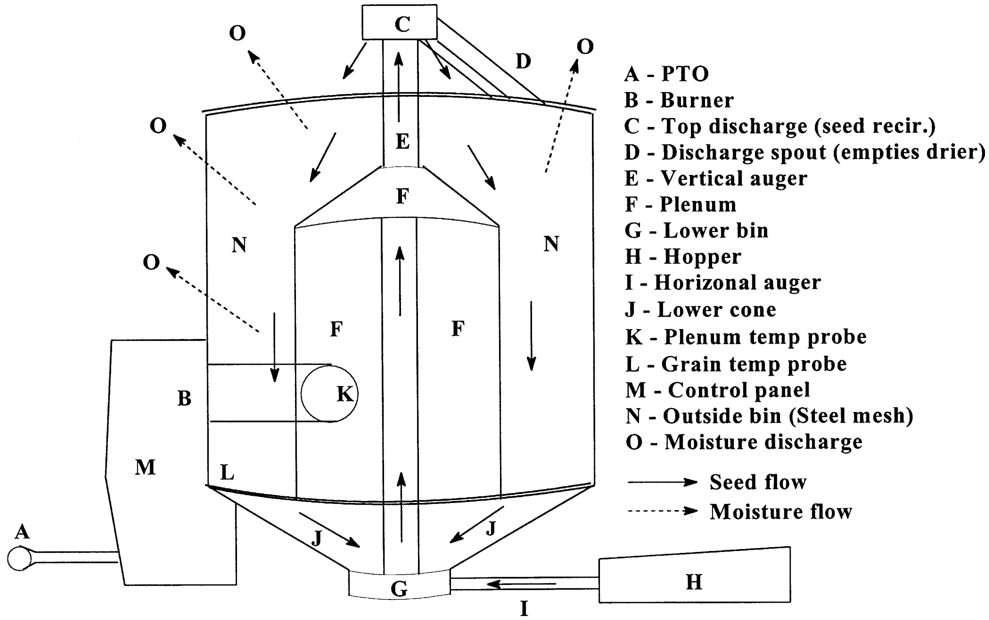

Fig. 1. Side view of grain dryer.

skin (Fig. 1, L). When the grain temperature gets above the dial setting, the control will automatically shut the burner off to prevent over-heating. The grain temperature control serves as an indicator to the degree of dryness. The grain temperatures for cuphea were recorded in Table 1.

2.2.1.3. Agitator arm modifications. The original arms with the grain dryer, Fig. 2, rotated both in the upper and lower portions of the lower cone, J, but did not come close to the drier walls. Both arms were redesigned to pass much closer to the walls, within 0.022 m. Arm-2, Fig. 2 (Modified), had the following

Table 1
Conditions for the grain dryer and laboratory determined moisture contents of cuphea seed

Entry	Time (min)	Seed temperature (°C)	Plenum temperature (°C)	Grain temperature (°C)	Seed wt. (wet) (g)	Seed wt. (dry) (g)	Moisture[a] (%)
1	0	29.4	–[b]	–[b]	12.89	6.31	51.1
2	55	22.2	65.6	33.3	10.10	5.08	49.7
3	75	22.2	60.0	34.6	9.91	5.11	48.4
4	95	21.1	57.2	34.6	9.33	5.34	42.8
5	115	21.1	65.6	37.8	9.62	5.71	40.7
6	135	18.9	60.0	37.8	9.97	6.34	36.5
7	155	18.3	60.0	37.8	10.31	7.05	31.7
8	175	17.8	62.8	37.2	10.56	7.52	28.8
9	205	16.1	62.8	37.8	11.41	9.41	17.6
10	215	15.6	60.0	40.0	10.07	8.62	14.4
11	225	15.6	51.6	37.8	11.51	10.10	12.3
12	–[c]	16.6	–[b]	–[b]	10.74	9.50	11.6

[a] moisture (%) determined by AOCS method in the laboratory.
[b] Does not apply.
[c] End – dry cuphea seed from drier.

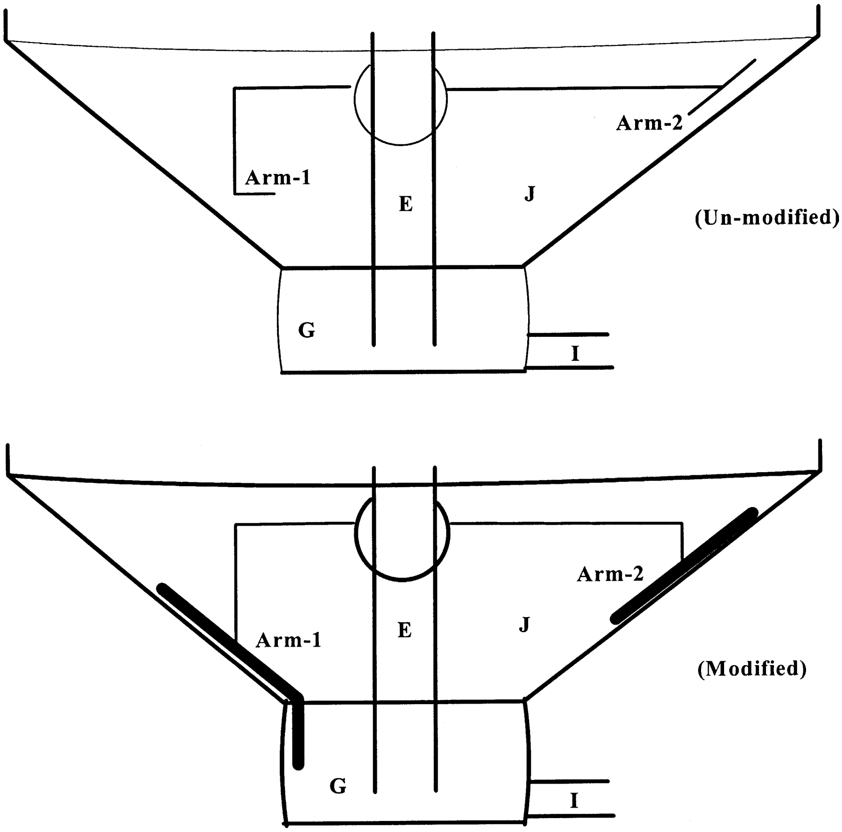

Fig. 2. Side view of un-modified and modified agitator assembly.

dimensions: width 0.011 m and length 0.61 m. Arm-1, Fig. 2 (un-modified), was also modified to extend lower down into the bin which helped with mixing in the lower bin. Arm-1, Fig. 2 (modified), had the following dimensions: width 0.011 m and length 0.76 m. The overall size of the arms was originally smaller. Thus, the size of the arms were increased to allow for better mixing and more contact with the seeds.

2.2.1.4. Loading the drier. The drier was loaded with the hopper attachment (Fig. 1, H). The PTO speed was reduced and horizontal auger, I, drive was engaged. The propane was turned on, the temperature set points were set and the burner was lit. The seed was unloaded from a pick-up truck by shovel into the hopper at such a rate as not to overfill the hopper or clog the lower bin. If very wet seeds and extremely dirty seeds were placed in the dryer, extreme caution was used in loading so that the dryer did not bind on the packed wet seed. The preferred method was to load small amounts, two hopper fills (Fig. 1, H) at a time and to make sure the seeds were mixing properly. When the dryer was overloaded with wet seeds, the lower bin and lower cone became plugged and the cuphea seeds had to be removed by hand out the bottom of the drier. After all the seeds were loaded into the dryer, the horizontal auger drive was disengaged and the PTO speed was increased to approximately 53.5 rad/s.

2.2.1.5. Unloading the dryer. After the seeds cooled, the PTO was stopped and the standard swivel discharge spout (Fig. 1, D) was swung into the unloading position. The PTO speed was slowly increased to approximately 53.5 rad/s and the seed was discharged out the spout.

2.2.2. Grain moisture meter

The G-7 Grain Moisture Meter is a meter that incorporates a double disc, pressure type electrode to measure moisture percent. The lower disc forms the base of a sample cup (0.040 m diameter) in which the seed sample is placed. The upper electrode screws down over the sample cup. Both discs have sharp points that are designed to penetrate the seed coat and make contact with the interior of the seed. The cup rests on a pressure plate that is mounted on a pre-tensioned calibrated spring, insuring uniformity of pressure from one test to another for optimum reproducibility.

2.2.2.1. Recording moisture percent. Seed samples were collected from the top of the grain dryer (Fig. 1, C). The samples were cleaned by hand to remove any large foreign matter. The seed moisture was measured in the G-7 Grain Moisture Meter. The sample cup was filled with the semi-clean seed sample and placed back on the pressure plate. The upper plate, electrode, was placed into position. The electrode screw was turned until resistance was noticed followed by one and one-half additional turns as noted in the manual. The moisture data from the meter are recorded in Table 2.

2.2.3. Laboratory moisture determinations

Laboratory moisture was determined using AOCS Method Ai 2-75 (Firestone, 1994).

3. Results and discussion

A very wet (>50%) batch of cuphea seed was dried using a Grain Technology, GT, 245XL Grain Dryer. The moisture was monitored (in 30 min intervals at start-up and then at 10 min intervals when seeds approached the target moisture levels) using the Delmhorst G-7 Grain Moisture Meter. A series of three batches were examined to determine the best method to dry the cuphea. Freshly harvested cuphea seed has a moisture level that is greater than 50%. During the 2000 harvest, seeds were dried on the floor of a covered building. This technique proved inadequate because the seeds clumped together and mold growth on the seeds was observed. To minimize clumping and prevent molding the seed was mixed by hand shovel which created a labor intense method. The need to dry these seeds economically and to ensure the quality of the seeds, a 245XL Grain Dryer was used for the 2001 harvest.

During the seed drying in 2001, additional problems were encountered due to the high moisture content of the seed. The first problem occurred as the cuphea seeds were loaded into the dryer and the heat was applied. The recycling of seeds (Fig. 1) appeared to proceed smoothly and the seed moisture decreased throughout drying, but upon unloading the seeds from the dryer a problem was discovered. The lower cone and lower bin (Fig. 1, J & G) were completely packed with wet cuphea seed even though seed sam-

Table 2
Moisture meter readings of cuphea seeds obtained with the meter set for the different crops

Entry	Time (min)	Corn (%)	Wheat(%)	Soybean (%)	Rapeseed (%)	Oats (%)	Hay (%)	Flax (%)	Cuphea[a] (%)
1	0	29.7	29.7	29.7	18.7	29.7	39.7	14.8	51.1
2	55	30.5	30.5	30.5	19.5	30.5	40.5	15.4	49.7
3	75	30.5	30.5	30.5	19.5	30.5	40.5	15.4	48.4
4	95	30.6	30.6	30.6	19.6	30.6	40.6	15.5	42.8
5	115	30.6	30.6	30.6	19.6	30.6	40.6	15.5	40.7
6	135	30.8	30.8	30.8	19.8	30.8	40.8	15.7	36.5
7	155	30.9	30.9	30.9	19.9	30.9	40.9	15.8	31.7
8	175	23.1	21.4	21.7	12.6	22.5	41.0	14.0	28.8
9	205	20.4	19.5	18.7	11.3	19.8	41.2	13.4	17.6
10	215	17.3	16.5	14.4	10.2	17.0	27.7	11.9	14.4
11	225	14.6	13.8	11.7	7.8	13.6	16.8	10.1	12.3
12	–[b]	14.5	13.7	11.6	7.8	13.6	16.7	10.1	11.6

[a] % moisture determined by AOCS method in the laboratory.
[b] End – dry cuphea seed from drier, based on laboratory measurements.

ples showed acceptable moisture levels. A channel had developed during the course of the drying in the lower bin through the wet seed. This allowed for the dry cuphea seeds to make their way through the dryer continuously, leaving the wet seed undisturbed and leading to an artificially low moisture level. The Grain Technology Grain Drier's original design proved to be inadequate for the high moisture levels and the small size of cuphea seed.

Before the 2002 drying season, the grain dryer, agitator and arm, were modified to eliminate inefficient drying. The original arms (Fig. 2) were both made larger and designed to come closer to the outside of the lower cone (0.0222 m). The modification improved air flow around the bottom of the cone in addition to breaking apart clumped seeds The larger arms were designed to help move more of the wet seed. The extension of the arm (Fig. 2, modified, Arm-1) down into the lower bin was most likely the most significant improvement. This allowed for mixing in the lower bin that was not achievable before. These modifications allowed the vertical auger (Fig. 1, E) to move seed to the top of the bin without becoming starved for material.

After the previously described mechanical modifications to the grain dryer were completed, all subsequent batches had thorough mixing in the dryer with no seed caking on the augers, sides or bottom cone of the equipment. During the drying process, a sample was collected from the top of the seed dryer (Fig. 1, C) and placed in a sealed vial for analysis the following day in the laboratory under methods described in Section 2.2.3, see results in Table 1. The moisture was initially greater than 50% and within 225 min the moisture was reduced to 12% with previously described drying conditions (Table 1). We targeted moisture contents around 10–13% with the intent that seed be used for both future grow-outs and seed oil processing. When moisture level was greater than 15%, we found that the seeds had a tendency to develop mold while being stored over the winter.

To provide farmers low-cost cuphea production methods, we developed a moisture calibration for a portable commercially available moisture meter. Many instruments are available to measurer moisture such as infrared, halogen, or Karl Fischer titration. However, these instruments are typically not economical for growers because they more than US $3000

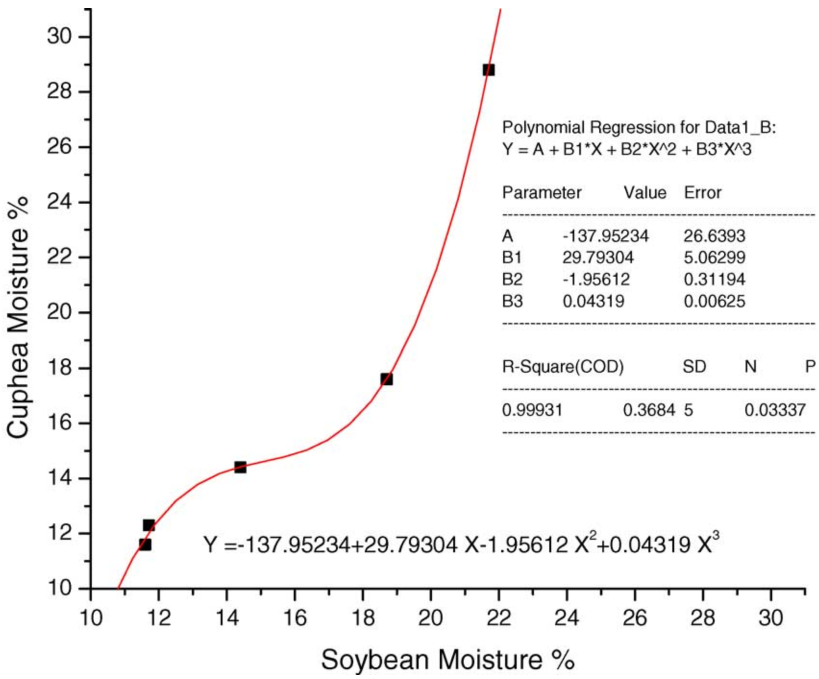

Fig. 3. Polynomial regression for soybean vs. cuphea moisture (%).

in 2004. They also lack portability provide real-time monitoring at the drying sites. The G-7 Grain Moisture Meter was used to develop a method to determine moisture contents of cuphea seeds and cost less than US $500 in 2004. This meter is suitable for many other traditional crops.

One of the disadvantages of the G-7 moisture meter was its limited upper range, as the meter could only record moisture less than 41%. The primary advantage of the G-7 moisture meter was the built-in temperature sensor, which measures the temperature of the seed sample and gives a temperature-corrected reading. The automatic temperature sensor allows for the displayed moisture to be temperature-corrected in the field as listed in Table 2.

The seeds were collected from the dryer were separated from foreign materials manually. The seeds were placed in the grain moisture meter and because there was no cuphea seed setting on the meter, a correlation to a known crop had to be developed. The moisture readings based on seven different crop settings were evaluated and are listed in Table 2.

All the factory settings selected gave moisture readings that decreased with time once the seed moisture percent was less than 40% (cuphea column, Table 2), as determined in the laboratory (Firestone, 1994). Once seed moisture was less than 20%, a strong correlation between the soybean reading and the observed laboratory values were found, Fig. 3. The cuphea moisture percent can be calculated with the following equation

$$Y = -137.952 + 29.7930X - 1.9561X^2 + 0.04319X^3$$

by substituting the soybean moisture percent into the equation for X. The rapeseed and flax settings on the moisture meter were the only two settings on the meter that gave moisture percentages below the actual cuphea seed moisture level, whereas the hay setting had the highest moisture at 16.7% for the end point.

4. Conclusions

Seeds from cuphea were harvested with a conventional concave cylinder combine and the seeds could be successfully dried in a commercial batch grain dryer. A modified GT 245XL Grain Drier enabled the reliable drying of small seeds containing more than 50% moisture at harvest. The seed moisture data was collected on a low-cost (less than US $500), commercially feasible G-7 Grain Moisture Meter. The meter when set on the soybean setting provided good correlation for cuphea seed moisture when the moisture level was below 20%.

Acknowledgements

Russ Gesch at USDA-ARS, North Central Soil Conservation Research Laboratory Morris, MN provided the cuphea seeds.

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